

Nationwide Urban Runoff Program USEPA
(United States Environmental Protection
Administration), Washtenaw County, Michigan
Evaluation of Urban Stormwater Runoff and
Management Practices for Controlling Urban
Stormwater Runoff: Summary Report

Environmental Control Technology Corp.
Ann Arbor, MI

Prepared for

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Summary Report - NURP
Nationwide Urban Runoff Program - USEPA
Washtenaw County, Ann Arbor, Michigan

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Summary Report

Nationwide Urban Runoff Program - USEPA
Washtenaw County, Michigan

Evaluation of Urban Stormwater Runoff
and
Management Practices for Controlling Urban Stormwater Runoff

for

James Murray
Drain Commissioner
Washtenaw County
Ann Arbor, Michigan

and

The Southeast Michigan Council of Governments
Detroit, Michigan

by

Environmental Control Technology Corporation
Ann Arbor, Michigan

March, 1983

Introduction

The Nationwide Urban Runoff Program (NURP) was undertaken by the USEPA in connection with the 208 Program in order to assess the effectiveness and the cost of selected urban stormwater pollution abatement techniques--termed Best Management Practices (BMP's). Evaluating BMP's nationwide was the policy option selected by the USEPA as the most prudent method of developing the body of information needed to correct and prevent pollution from urban stormwater runoff. The 208 Program resulted in the collection of much water quality data, but very little information exists, or has been collected by 208 heretofore, on the cost and effects of water pollution control techniques. NURP supported the evaluation of selected BMP's throughout the country, and based on such evaluations, will determine which BMP's are cost-effective in a particular situation and at a given scale. This approach is yielding data which is comparable within and between geographic regions. A collection of information will be available at the conclusion of NURP which will provide guidance to Federal, regional, State and local agencies responsible for implementing the Areawide Water Quality Management Plans.

This project was the result of a grant to the Washtenaw County Drain Commissioner's Office, through the 208 planning agency (SEMOG), from the NURP program of the USEPA. The blending of the goals of the NURP program with the findings of the 208 study and the interest and control of the Drain Commissioner over stormwater management and drainage systems presented a natural sponsoring team for the program.

The primary objective of this study was to evaluate the effectiveness of Best Management Practices (BMP's) in reducing the pollutant loads present in urban stormwater runoff. Four specific BMP's were selected for evaluation:

- 1) Surface Retention Basin
- 2) Surface Detention Basin
- 3) Natural Wetland
- 4) Runoff Ordinance

In addition to the primary objective, objectives of this study included estimation of the quantity and sources of urban runoff pollutants entering the Huron River in the study area, and assessment of the impact of these loads on water quality in the river with and without the use of BMP's. The findings of this report represents the efforts of a two year sampling program.

Study Area

The Huron River Basin is located in Southeastern Michigan and discharges directly to Lake Erie. The terrain represents a typical Michigan landscape with gently rolling topography. Soils range from sands to heavy loams. The average rainfall is 32 inches per year of which 3 to 4 inches occurs as snowfall. The average storm event is 0.3 inches. Summer storms are usually localized, convective in nature, intense and of short duration.

The section of the Huron River specifically being addressed in this study is the reach flowing through the City of Ann Arbor from Argo Dam to Geddes Dam. This reach of river is a mixture of free flowing water and a large impounded area created by Geddes Dam. The river discharges from Argo Dam and flows freely for approximately 3 miles

before entering the Geddes impoundment. Geddes Pond is approximately 5×10^7 cubic feet in volume and is a significant feature of the river in the urban area. In this reach of the Huron River five major separate storm drains discharge stormwater runoff. The five drains; Allen, Traver Creek, Swift Run, Pittsfield-Ann Arbor, and North Campus are part of the study program with BMP's being located in three of these drainage systems. Each of these five drainage districts were monitored during this program and consequently specific descriptions of each drain were developed for the fixed site data base program for NURP.

The general land use in this portion of the Huron Basin is a combination of urban area and agriculture land. The urban area of Ann Arbor is primarily residential in character with a substantial amount of parkland spread throughout the city. There is very little heavy industry in the city. Commercial areas are located in the downstream area, in shopping malls, and along major arteries. The city has developed in this manner due to the strong influence of the University of Michigan. The major economic base in the city is in high technology research type companies and professional service organizations. Thus, overall the city is primarily a residential area with commercial areas to support the population of 110,000 and to provide office and laboratory type space.

As mentioned earlier, the BMP's are located on three of the five major storm drains that discharge into the Argo Dam -- Geddes Dam reach of the Huron River. The retention basin is located in the Pittsfield-Ann Arbor Drainage District, the wetlands is located in the Swift Run Wetlands Drainage District and the detention basin is located in the Traver Creek.

Drainage District

The retention basin in Pittsfield-Ann Arbor Drain Drainage District receives runoff from two large subdistricts, one to the north and one to the south and west. Each of these districts was monitored separately during the study. The south sub-district is approximately 31% of the total area and is the Western and Southern portion of the district. In this area is located a regional shopping center, a local airport, an industrial and research park, and much land devoted to "open" uses, i.e., farming, woodlots, and vacant. The watercourse providing drainage is open, but has been greatly channelized. There are five "wet" on-line retention ponds on the shopping center site, and another on-line "wet" retention pond on the drain downstream of the research park and airport, as well as being downstream of the shopping center. This sub-district contains the highest proportion of open space and the least percentage of impervious area.

The second sub-drainage area is the largest one, accounting for approximately 46% of the total area. This area lies in the northern section of the District and the flow from it is southerly. The drain is entirely enclosed. This sub-district is characterized by having older and more developed urban land covers than either of the other two sub-districts. Land uses include a major university, medium and high density residences, and some strip commercial.

The Swift Run Drainage District is approximately 3100 acres. The drainage area above the wetland is 1207 acres. The stream flows northeasterly from its origin in Section 15 of Pittsfield Township and is open throughout most of its course.

Land use in the upper portion of the district are open and agricultural in nature. The impact of urbanization begins with the City of Ann Arbor's 110 acre landfill located adjacent to the Drain immediately south of Ellsworth Road. Immediately north of Ellsworth Road is located a high density residential townhouse development.

The wetland has been acquired by the Office of the Drain Commissioner in order to incorporate storage and water quality improvement into the design of the project. From this point to the outlet of the drain at the Huron River the drainage district has been almost completely developed with urban, and residential uses. Commercial strips also occur south of the wetland. The impervious surface increases and the roads are paved with curb and gutter drainage (but no catch basins with sumps).

The Traver Creek Drainage District is made up of 4400 acres. The drainage area above the detention basin is 2300 acres of which 1860 acres are dedicated to agricultural land uses. From the detention basin to the outlet of the drain at the Huron River the majority of the drainage district is comprised of 1500 acres of parkland and 370 acres of high and medium density residential land uses. The watercourse flows continuously throughout the year although the very flat grade of the streambed north of the detention basin coupled with the previous, agricultural covers produces a stream of low velocity and with rooted vegetation growing up to the water's edge. Excepting road culverts, the stream is totally open.

Best Management Practices

The study area was selected based on the findings of the 208 program from the region which targeted this area as an urban non-point source problem area. The concern and effort of the Washtenaw County Drain Commissioner to address this problem resulted in the availability of the in place Best Management Practices (BMP's) evaluated during this study.

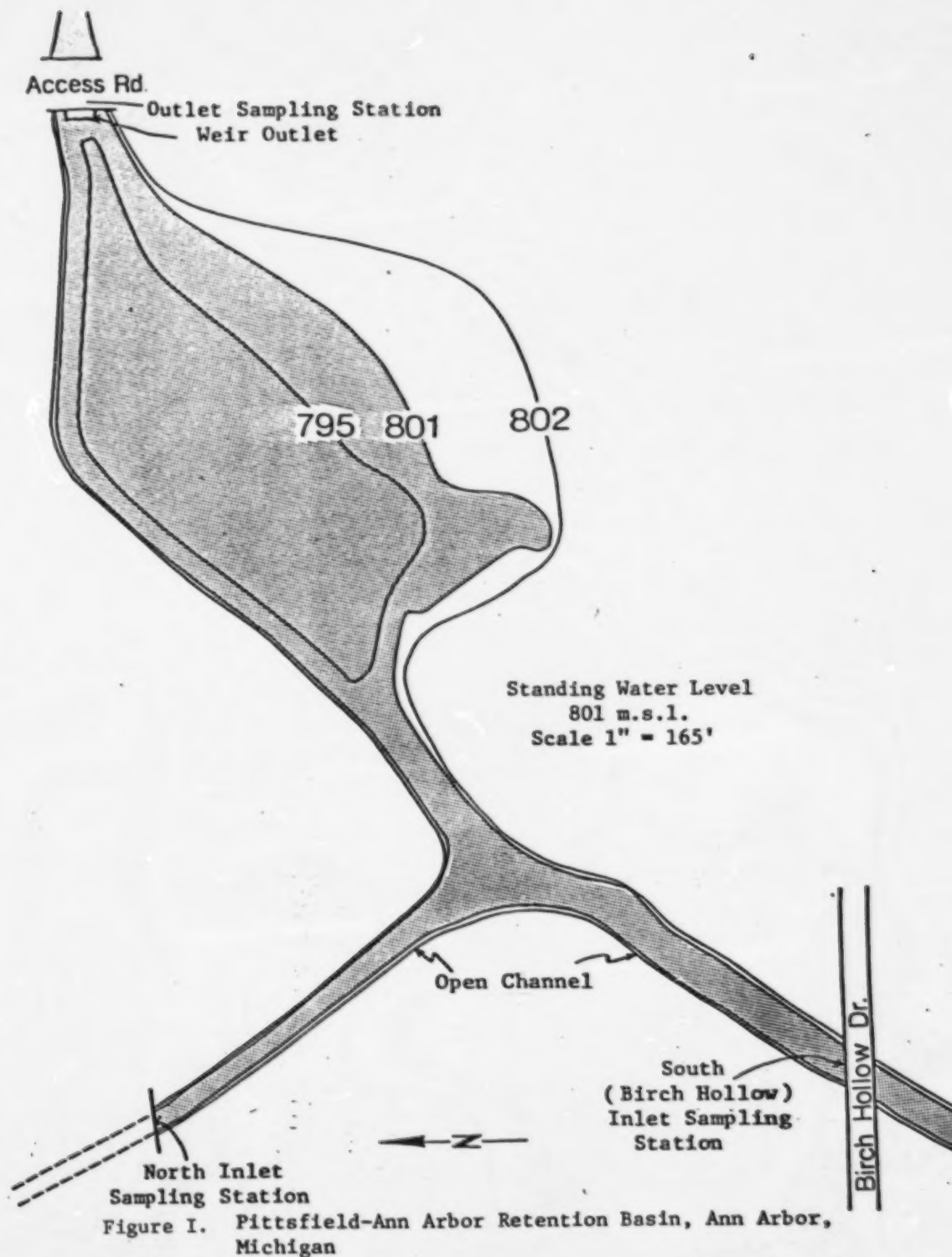
On-Line Retention Basin

Design Specifications

The initial design of the basin was to provide flood relief to downstream sections of the drain. However, the basin may also provide water quality benefits to the downstream area and Huron River. It was the objective of this study to obtain water quality data on the "as built" inherent capability of this basin to reduce pollutant levels occurring in the storm water entering the basin. Some changes in water quality were expected to occur due to sedimentation processes and possibly through biological activity.

The basin shape is illustrated in Figure I. Water enters the basin from the west and exists to the east. There are two main tributaries discharging to the basin. These tributaries join into a single entrance channel several hundred feet upstream of the actual basin entrance.

A permanent water elevation of 801 is maintained in the basin with a permanent storage capacity of 914,760 cubic



feet. An additional design capacity of 6,734,376 ft³ occurs at elevation 807 with a maximum design flow of 2,916 cfs at this elevation. Depth-volume relationships are given in Table 1.

The outlet structure for this retention basin is a rectangular broadcrested weir which controls water elevation and discharge. This structure was designed only to attenuate flood flows and does not severely restrict flow at varying runoff rates. The overflow weir is approximately 60 feet in total length including both front and side surfaces. The depth of the water at the weir is approximately 1.5 to 3 feet measured during dry flow conditions.

Retention Basin Capital Costs

The construction of the Pittsfield-Ann Arbor retention basin and associated drain improvement projects was undertaken primarily in the construction seasons of 1977 and 1978. The costs of constructing the retention basin are shown in Table 2. These costs were based on the actual contractor costs as charged during the project. Land acquisition costs were reasonably high (approximately \$12,500/acre) because of the location within a developed portion of the City. Engineering and legal fees were standard fees based on percentage of construction.

Table 2 Capital Costs Pittsfield-Ann Arbor
Retention Basin

Land Acquisition	\$128,750.00
Construction Costs	\$186,026.30
Engineering Fees,	\$ 20,000.00
Legal	

Table 1. Depth-Volume Relationship

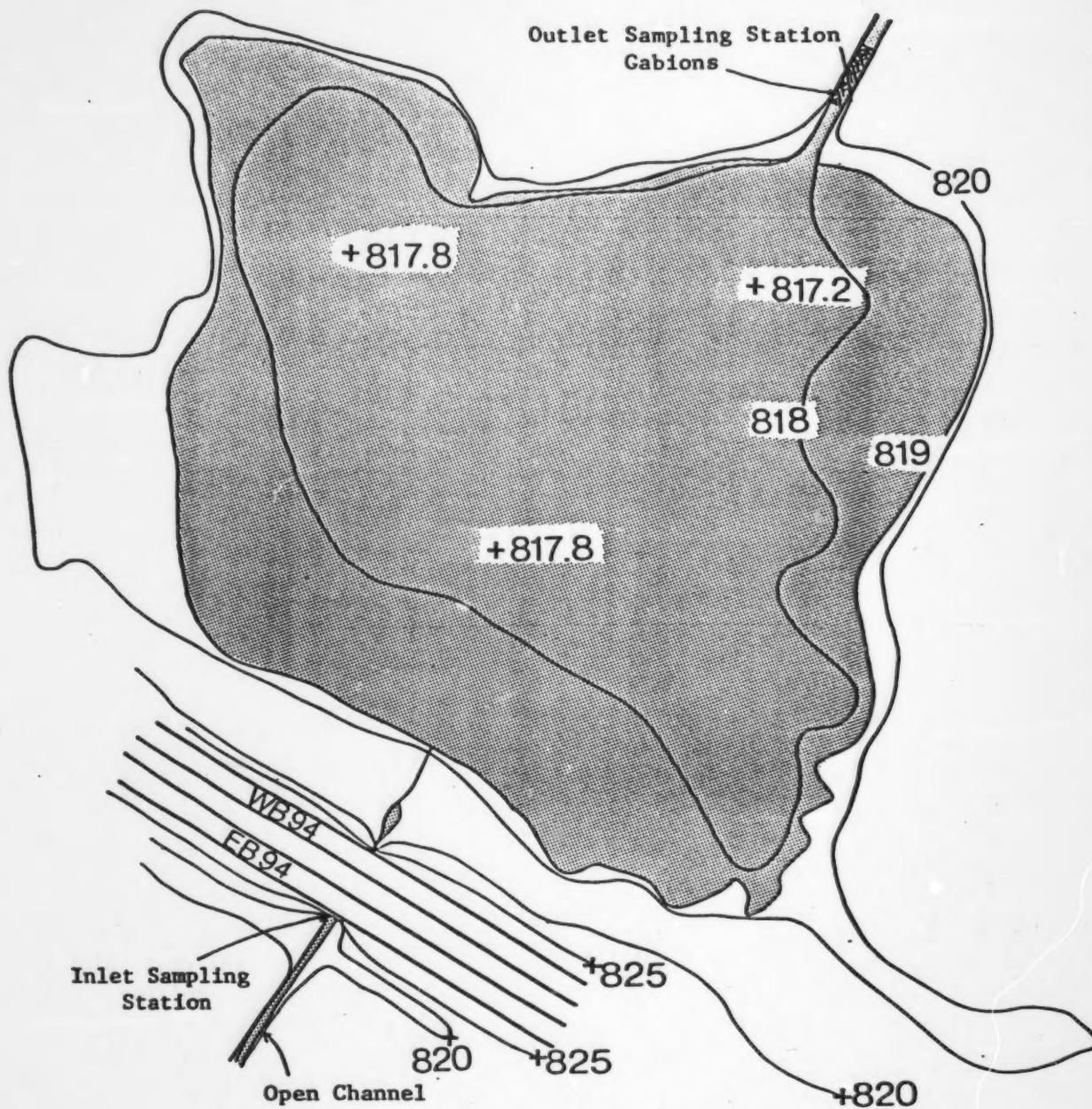
Elevation	Stage	Surface	Capacity (cu. ft.)	Discharge (CFS)
	Feet	Area (ft ²)		
801	0		914,760	0
802	1	226,510	1,141,270	198
803	2	383,330	1,681,420	561
804	3	588,060	2,678,940	1,031
805	4	834,175	4,251,460	1,587
806	5	1,048,900	6,159,384	2,218
807	6	1,122,400	7,649,140	2,916

Natural Wetlands

Design Specifications

Natural wetlands have the ability to accomplish many of the stormwater management objectives of artificially constructed retention basins. Wetlands can reduce stormwater velocity and buffer peak flows so that pollutants can settle out and also offer tremendous flood control abilities. Besides offering ways to improve the quality of stormwater runoff, wetlands also provide fish and wildlife habitats, recreational opportunities and aesthetic beauty. This naturally occurring wetland was investigated as a BMP for its capability to reduce total suspended solids, BOD, nutrients and metals contained in stormwater runoff from the upstream townhouse development and landfill.

The shape of the wetlands is illustrated in Figure II. The average depth ranges between one and two feet. The wetlands is designed to sustain a permanent water elevation of 819 with a permanent overflow structure which will handle flows generating heads up to 3 feet or elevation 822 (See Table 3). This yields a storage volume of approximately 2.6×10^6 cubic feet. This storage volume is sufficient to maintain outlet flows from the wetlands at rates equal to or less than 160 cfs., the capacity of the downstream storm sewer during a 25 year, 24 hr. duration rainfall. The controlling outlet structure is a trapezoidal weir with gabions lining the sides and bottom of the channel.



Standing Water Level: 819 m.s.l.
1" = 150'

Figure II. Swift Run Wetland BMP, Ann Arbor, Michigan

Table 3. Depth Volume - Discharge Relationship Swift Run Wetlands

Elevation	Stage Feet	Discharge CFS	Volume (cu.ft.)	Surface Area Ft. ²
819	0	0	630,000	419,900
820	1	16	927,500	615,800
821	2	66	1,647,200	823,500
822	3	166	2,621,000	1,077,000

Natural Wetlands Capital Costs

The Swift Run Wetland was a natural wetland which originally outlet via a natural drainage course (creek). The only construction required at the wetland was the building of a control structure at the outlet. The control structure was required to provide flood relief for downstream areas by utilizing the full capacity of the wetlands. Bank improvement around the new outlet structure was also required to prevent overland flooding at high stage levels.

Table 4 shows the capital costs associated with the wetland improvement project. The construction costs for the outlet were based on actual cost to build the structure plus bank improvements. As shown in Table 4, the land acquisition costs was the major item in the budget. The

wetland area was part of very large lots on which homes had been built on the higher area of each lot. Thus, it was necessary to purchase land from several owners in order to control the wetland area. The payment to these land owners was the major cost of the project. Legal fees were also quite high for this project due to negotiations with some of the land owners. It was necessary to carry out condemnation proceedings to obtain a few parcels of land.

Table 4 Capital Costs
Swift Run Wetlands

Construction Costs

Outlet Structure	\$ 33,750.00
Total	33,750.00
Land Acquisition	101,000.00
Engineering and Legal Fees	15,000.00
Total	\$149,750.00

NOTES: Only construction required was outlet.
Wetland was naturally present

Legal fees were high because of condemnation procedures needed to acquire the land.

Surface Detention Basin

Design Specifications

The basin was originally designed to provide detention of water for flood control and water quality improvement by sedimentation. The basin was designed as an off line basin which received water during high flow periods via a diversion channel. During high flows, the capacity of an overflow structure located in the normal creek bed would be exceeded, resulting in water being diverted to the basin. The purpose of using this approach was to provide a dry basin during dry weather, allow for the maintaining of normal dry weather creek flows, and to allow for increased holding time in the basin of the high flow waters by severely restricting the flow from the basin.

Several factors changed the original basin design and affected the basin conditions. The most important factor to this study was the construction schedule. Construction of the basin and outlet structures had been started in 1980 but due to delays in construction was not completed until late in the summer of 1981. These delays forced modifications in the BMP sampling program. By March of 1981 the bypass structure was the only item that needed to be completed. The drain had been rerouted by means of a temporary ditch directly into the basin. Since the bypass structure was not scheduled to be completed until the end of the summer of 1981, it was decided to monitor the basin as an on-line retention basin. No construction activity took place during the actual monitoring period (April-June). The objective of the evaluation of this basin was to determine the level of water quality improvement which could be expected from this

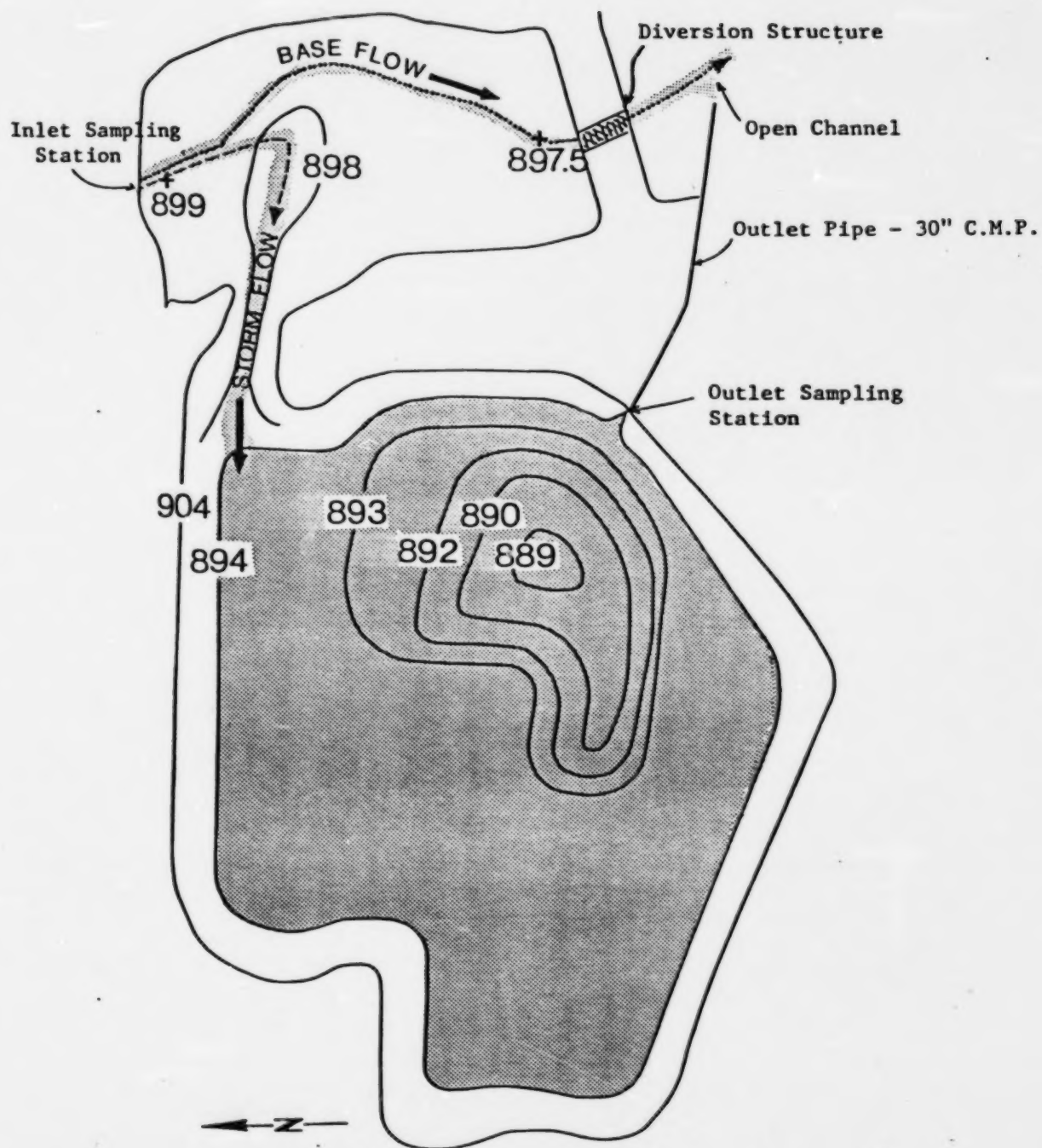
type of on-line basin even though in this case the basin when completed would act as an off-line retention basin. The depth-area volume-discharge relationships for this basin using the actual conditions observed during the project are presented in Table 5. Figure III shows the general shape of this basin.

Table 5. Depth Volume - Discharge Relationship
Traver Creek Retention Basin

Elevation	Stage Feet	Discharge CFS	Volume (cu.ft.)	Surface Area Ft.
894	0	0	512,000	290,000
896	2	5.8	1,116,000	308,000
898	4	6.7	1,756,000	326,000
900	6	10.2	2,432,000	344,000

Traver Creek Retention Basin Costs

The Traver Creek retention basin is located in a former gravel pit area. The location and topography necessitated a large amount of earth work in this area. The basin area and outlet structures were designed for the 1 in 200 years storm due to requirements by the Michigan Highway Department. This design basis is for a much larger event than is normally considered for urban flood control. In addition, because the original design was for a dry off-line basin, a second control structure to maintain base flow in the creek was required. These factors should be carefully considered when reviewing the cost figures and will undoubtedly require adjustment if these costs are applied for other areas.



Standing Water Level: 894 m.s.l.
1" = 150'

Figure III. Traver Creek Detention Basin, Ann Arbor, Michigan

Table 6 shows the construction costs and other fees for the basin. The construction costs were based on the bid documents for the project. Engineering and legal fees were based on a percentage of the total project costs. No land acquisitions costs were required for this project as the land was owned by the government.

Table 6. Capital Costs Traver Creek Retention Basin

Construction Costs	\$229,515.00
Engineering Fees, Legal	\$ 23,000.00
Land Acquisition	0

Monitoring and Analytical Program

General

The selection of water quality sampling stations and water quality analyses to be performed was based on the objectives of monitoring the inputs of the various drains to the Huron River, determination of water quality in the river during and following storm discharges, and the measurement of water quality conditions into and out of the various BMP's under investigation. Five stations for the measurement of flow and collection of composite water samples were established at the outlets of each of the five drainage districts discharging into the Geddes Pond Area of the Huron River. In addition, two stations were established on the river itself one upstream of the drains at Argo Dam and one downstream at Geddes Dam. Water quality monitoring stations were also established on the two inlet tributaries to the Pittsfield-Ann Arbor retention basin, on the outlet from the basin, on the inlet and outlet of the Swift Run Wetlands and on the inlet and outlet of the Traver Creek Retention Basin BMP's.

River and Drain Outlet

Sampling stations were established at the outlets of each of the five main drains entering Geddes Pond (Spring 1979). The stations were located as near the mouth of the drain as possible without being influenced by backwater effects. This was possible for all drain outlets except Allen Drain where the low flow was affected by the cycling of Argo Dam. A rating curve was established to account for this problem and at higher flows during a storm the backwater effects were negligible. Each station consisted of a continuous level recorder and a Manning automatic sampler for taking discrete samples. Equipment was housed in steel boxes for security. Float switches were used to activate the sampling equipment. All of the drains were open drains with the exception of Allen Drain which is an enclosed system. In each case the flow monitoring station was established at a bridge or culvert so that a predictable cross sectional area was available.

The sampling stations for the river were established at Argo and Geddes Dam. Automatic sampling equipment was placed on the dam structure and samples were collected where the water passed through the dams. Level recording equipment measured water elevation changes which were utilized in conjunction with design rating curves to determine flow. A U.S.G.S. monitoring station is located just downstream of Argo Dam which served as a check on the flow data.

BMP Monitoring Stations

Monitoring stations were established at the inlets and outlets of each BMP to obtain flow and water quality data.

Water quality samples were collected using automatic sampling equipment on a time basis. Discrete samples were collected at fifteen or thirty minute time intervals. Flow data, obtained from continuous level Stevens recorders, was then used to composite the discrete samples on a flow proportionate basis. One exception to this, however, was the Swift Run Wetlands Outlet where a Manning flow recorder automatically pulsed the sampler for a flow proportionate sample. Generally, for the rainfall events, one to two composites were made to represent the major runoff portion of the event, and one or two additional composites were made to represent the tail portion of the curve and background conditions. Thus, a series of sequential composite samples were obtained to represent each runoff event.

The flow data for the drains was obtained from the level recorders through the use of a developed stage discharge curve. The curve was based on a series of depth and velocity measurement taken over a range of flow during dry and wet weather periods. Water depths were manually read from the recorder charts and plotted or charted as flow-time relationships for each event.

Precipitation data was obtained from a continuously recording, weighing bucket rain gage. This rain gage provided both intensity and total volume of precipitation for each rainfall event. The gage was located approximately two miles from the retention basin and adjacent to the Swift Run Drainage District.

Analytical Protocol

The complete analytical program for this project is shown in Table 7. The results for selected parameters are given in this paper. Analytical methods utilized are approved USEPA methodology.

To ensure the reliability of the data base, a site specific quality assurance program was developed in addition to standard quality assurance procedures. Both field and laboratory procedures were incorporated in the quality assurance program. The main areas of the field quality assurance program included frequent calibration and verification of equipment specifications, periodic velocity and depth measurements to verify flow, collection of field blanks, duplicate samples and duplicate composite samples to check sample splitting techniques. Laboratory procedures included duplicate analyses, spiked samples, split samples, and performance evaluations of unknown samples provided by USEPA Region V.

Table 7. Monitored Chemical Parameters

<u>Primary Analysis</u>	<u>Periodic Sample Analysis</u>
Total Suspended Solids	Grease and Oil
Total Dissolved Solids	Total Cadmium
Particle Size Distribution	Total Zinc
pH/Alkalinity	Total Chromium
Nitrate Nitrogen	Total Nickel
Total Kjeldahl Nitrogen	Fecal Coliform
Soluble Kjeldahl Nitrogen	Fecal Streptococcus
Total Phosphorus	
Soluble Phosphorus	
Chemical Oxygen Demand	
Biochemical Oxygen Demand	
Total Iron	
Soluble Iron	
Total Lead	
Soluble Lead	

Results and Discussion

Pittsfield-Ann Arbor Retention Basin

Results

Six rain events and one snow melt event were monitored during the study period. Summaries of selected pollutant loadings entering and leaving the retention basin are shown in Table 8. These summary tables are based on loadings occurring during the runoff period corrected for base flow levels. Thus, the levels represent the load due to runoff.

This correction for background level is important during small storms as will be discussed later. The loadings for each storm were calculated from the sequential flow proportional composite samples collected during each event. The sequential composite samples provided detail data on the various portions of the hydrograph but have been combined into total loads and average concentrations for this paper.

Continuous flow recording at each station provided a good description of the runoff characteristics from the two subdistricts entering the basin. The North subdistrict, a totally enclosed system, was fairly flashy with high peak flows and rapid return to baseflow conditions. The South subdistrict, an open channel drainage system with retention basins, exhibited tempered peak flows and a more broad hydrograph with a long tail portion.

An overall comparison of the flow data collected at the inlet stations and the outlet showed that the volume of

Table 8. Summary of Pollutant Loads
Pittsfield - Ann Arbor Retention Basin
Washtenaw County Michigan

Station	Date	Rain Inches	Runoff Volume 10 ⁶ cu. ft.	Runoff Coeff	TSS lbs.	T-P lbs.	TKN lbs.	T-Fe lbs.	T-Pb lbs.
Inlet	06/30/79	2.25	3.9		23400	49	262	539	16
Outlet			3.9	0.10	13000	36	258	502	8
% Rem		0.25	0.53		44	27	4	7	50
Inlet	10/22/79	0.25	0.53		920	5.1	16	29	0.7
Outlet			0.59	0.13	500	1.2	16	17	0.2
% Rem					54	82	--	41	71
					11**	55**		21**	60**
Inlet	08/10/80	0.40	0.66		1500	4.0	30	31	1.0
Outlet			0.66	0.15	480	3.2	21	24	0.6
% Rem					68	20	30	23	40
					39**	0**	0**	5**	34**
Inlet	09/09/80	0.90	2.3		6500	21	150	230	< 11
Outlet			2.3	0.14	5700	18	135	210	1.2
% Rem					12	14	10	9	> 90
Inlet	09/17/80	0.67	27		7100	23	150	210	2.1
Outlet			27	0.23	5900	21	110	170	1.8
% Rem					17	9	27	19	12
Inlet	10/24/80	0.45	1.0		2950	15	44	110	2.0
Outlet			1.0	0.13	440	11	22	30	1.1
% Rem					85	27	50	72	> 45
					57**	17**	9**	52**	> 45**
Inlet	02/17/80	Snow Melt	12.4		75000	218	1300	1600	21
Outlet			11.5		54000	274	1100	1300	30
% Rem					27	--	15	19	--

** Unadjusted values include baseflow in load cal.

runoff water balanced quite well with inlet and outlet volumes within 10% for all measured events. Dissolved solids data was also compared to provide a basis for evaluating the sampling program and again balances were within 10% and generally better. Runoff coefficients calculated from rainfall and runoff data are shown in Table 8. As can be seen the runoff coefficients are fairly constant for the rain events. The higher values found in September 1980 can be explained by the weather conditions preceding these events. August 1980 was an extremely wet month and several large rain events occurred in September. Ground conditions approached saturation and were conducive to higher runoff rates. Individual rain intensities also appeared to influence the runoff volume as shown in the September 9 data when 0.9 inches of rain fell in a two hour period.

The overall removal efficiency of the retention basin for suspended solids ranged from 10-85 per cent. The removal efficiency appears to be highly dependent on a number of factors which include detention time, basin design, outlet structure design and baseflow concentrations. As shown in the October 1979 storm survey, a small rain will show low removal efficiency if total unadjusted loads are utilized. As an example, accounting for baseflow levels in calculating per cent removal, the October storm changes from 11% unadjusted to 54% removal of TSS. This is due to the relatively low loading of the storm and comparatively high baseflow concentrations. The background suspended solids level in the retention basin is in the range of 14-17 mg/l. This level of suspended solids is higher than is generally found in storm drains in the area during dry weather.

A summary of the particle size data presented in Table 9 shows a clear shift in particle size distribution between the inlet and outlet stations. The outlet station has a larger percentage of smaller sizes reflecting the settling of the larger particles in the basin as would be expected. In addition, a comparison of particle size distribution between the two inlet stations shows that the south arm inlet generally has a larger percentage of smaller particle size than does the north inlet. This would reflect the fact that the south arm has several retention basins upstream from the sampling point and settling and removal of suspended solids is already taking place in these upstream basins.

Total Kjeldahl Nitrogen removal varied from 0-50% when background levels were accounted for and were very low on a total load basis. Part of the reason for the lower removal can be explained by the fact that more than 50% of the TKN was in the soluble form.

Phosphorus removal efficiency varied greatly ranging from 0-82%. Measurements of soluble and insoluble phosphorus showed that most of the phosphorus was in the insoluble form. This would suggest that removal of phosphorus should coincide with TSS removal levels. However, no statistically significant relationship between T-P and TSS removal could be determined.

BOD and COD removal efficiencies were low (10-20%), however the levels of oxygen demanding materials were also relatively low (BOD 2-12 mg/l, COD 25-50 mg/l). These low levels are typical of Ann Arbor drainage systems. Grease and oil was not retained in the retention basin. This fact would indicate that the grease and oil do not adsorb to the suspended solids which are settling, but rather are surface oriented and carry over at the outlet structure.

Table 9. Range of Particle Sizes
Pittsfield-Ann Arbor Retention Basin

Station	Size	Ave	Min - Max
	Micron	% wt	% wt
North Inlet	> 60	10	0-20
	4-60	70	40-90
	< 4	20	5-60
South Inlet	>60	10	0-25
	4-60	65	50-80
	< 4	25	20-50
Outlet	>60	0	0
	4-60	58	30-70
	< 4	42	30-70

Heavy metals results shows that metals do settle out consistently. However, the removal efficiencies do vary. These variations in removal efficiencies can be associated with the variations seen in the total suspended solids removals. In general the metals are mostly in the insoluble form and would be expected to be associated with and influenced by sedimentation processes. Long settling times in the basin result in better removal efficiencies as is true with total suspended solids removal. Lead has the greatest and most consistent removal efficiencies among the heavy metals monitored.

The results of the fecal coliform monitoring program indicate that the retention time in the basin is not long enough for coliform die off to occur. Coliform levels that enter the basin usually leave at similar concentrations. Ranges of fecal coliforms levels are shown in Table 10.

Examination of the snow melt data shows that runoff during snow melt periods contribute large quantities of pollutants to both inlet branches of the Pittsfield-Ann Arbor Retention Basin. Table 8 summarizes the pollutant loadings found during the February 1981 snow melt event. This was the major snow melt of the winter after which most areas were clear of snow. The data indicates that the retention basin does have some removal capability for all parameters monitored with total suspended solids and total iron having the highest removal efficiencies. Particle size data indicates that generally snow melt runoff contains larger particle sizes overall in comparison with rain event survey periods. This would tend to indicate that snow melt runoff may be more effectively controlled by sedimentation than rainfall runoff waters. As seen in rainfall events,

total kjeldahl nitrogen is present more in the soluble form, whereas the metals are prevalent in the insoluble form. Soluble phosphorus is also slightly more prevalent than insoluble phosphorus during the snow melt period. Fecal coliform levels are found to be low for both inlets and resulted in the low levels of the range shown.

Comparing event mean concentrations (EMC's) of the snow melt event to the rain event's indicate that on the South Arm inlet the EMC's for most parameters (TDS, TSS, TKN, SKN, TP, SP, COD, T-Fe, S-Fe) monitored were considerably higher during the snow melt than found during the rain events. However, this was not found to be the case on the North Arm inlet. Event mean concentrations on the North inlet for the snow melt tend to be in the same range as those monitored during the rain events. A summary of the concentration's is shown in Table 10.

Discussion

It was anticipated that removal of pollutants in the Pittsfield-Ann Arbor retention basin would primarily be accomplished by sedimentation of suspended materials. The principle factor which affects sedimentation efficiency under ideal conditions is the detention time provided in the basin. In an ideal basin the detention time will determine the critical settling velocity. All particles having settling velocities higher than the critical value will be removed from the basin. However, many real world factors affect the actual performance of a basin and the magnitude of the deviation from ideal conditions will determine the actual efficiency achieved.

Table 10. Range of Inlet and Outlet Event Mean Concentrations
Pittsfield - Ann Arbor Retention Basin

Parameter		Min	Max	Ave	Events
TSS (mg/l)	South In	23	102	53	7
	North In	41	136	70	7
	Outlet	22	75	40	7
TP (mg/l)	South In	.04	.33	.13	7
	North In	0.16	0.5	.26	7
	Outlet	.07	.38	.17	7
TKN (mg/l)	South In	0.5	1.9	1.0	7
	North In	0.7	1.4	1.1	7
	Outlet	0.7	1.6	0.9	7
T-Fe (mg/l)	South In	0.8	2.1	1.4	7
	North In	1.1	2.9	1.9	7
	Outlet	0.8	1.9	1.2	7
T-Pb (mg/l)	South In	.003	.02	.01	7
	North In	.02	.07	.04	6
	Outlet	.01	.04	.02	7
Fecal Coliform					
Cfu/100 ml					
	South In	1100	300,000		20*
	North In	1100	2,900,000		20*
	Outlet	1000	740,000		20*

* Total number of individual samples

Table 11 shows the average and minimum theoretical detention time (based on volume displacement) in the retention basin for each of the monitored runoff events. Peak suspended solids concentration, the event mean concentration, and overall percent removal levels are also shown. Suspended solids data are provided as this parameter is the primary constituent influenced by sedimentation. Other materials in the particulate form will follow the suspended solids levels to some degree depending on the size and specific gravity of the particles with which they are associated.

The performance of the retention basin (based on % removal of the total load) is lower than was initially projected using ideal basin assumptions at the beginning of the study. Several factors appear to be influencing the actual performance of this basin including site specific conditions and the basin design. Site specific conditions need to be understood and accounted for when using the results of this work in other applications. Basin design factors can be altered in future basin designs to improve the basin performance.

Two main factors, background suspended solids and other pollutant concentrations, and the particle characteristics for this drainage system, directly affect the percent removal levels measured for the basin. Using the ideal basin approach it would be expected that during smaller storms with lower peaks and average flows (i.e. longer detention times) that the performance of the basin on a percent removal basis would be the highest. However, as shown in Table 11, the October 1979 storm which was a small event, had the lowest overall percent removal. The calculation of this removal percentage, however includes all

Table 11. Detention Time for Monitored Events
Pittsfield - Ann Arbor Retention Basin

Date	Min. Detention* Time (hrs.)	Ave. Detention* Time (hrs.)	% TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS Conc. (mg/l)
Snow Melt 1981	2.5	3.7	27	110	75
06-30-79	2.5	23	44	79	51
09-11-80	2.6	19	10(26)**	52	47
09-17-80	4.6	15	17(14)**	40	34
10-24-80	7.3	32	57(87)**	24	22
08-10-80	7.7	36	39(70)**	28	27
10-22-79	37	105	9(45)**	43	27

* Theoretical time based flow rate and volume displacement.

** Background corrected.

of the load during the monitoring period including both the background suspended solids level and the increase load during the storm. In the case of small storms, the background level in the retention basin (12 mg/l TSS) is a significant load compared to the event mean concentration of 16 mg/l for the October storm. Recalculating the removal efficiency for this storm by subtracting normal background levels results in a removal efficiency of 45%. Other pollutant removals are also impacted by background levels. The impact background concentrations have for these other parameters is shown in Table 8.

The impact of the background levels highlight that when examining and reviewing the rain event runoff data, care must be taken not to place too much emphasis on the actual percent removal of various materials but rather consider the removal amounts and types of mechanisms affecting the materials controlled.

A site specific condition of the South Arm inlet which effects both the total load during events and the background level, is that other retention basins upstream will tend to reduce the amount of pollutant which is available for removal. The north arm has no control on it and thus represents the total load coming from that drainage area. The south arm drainage area (2001 acres - 21% impervious) includes a large shopping center and airport but also contains several retention basins controlling the runoff from these developments. Based on land use characteristics and findings during the drain outlet survey and previous work, the runoff water from the south arm would be expected to be at least as contaminated on a concentration or per acre developed basis as the north arm area (2871 acres - 26% impervious). Examination of the data, however, shows that

there is a dramatic difference between the event mean concentrations in the south arm and the north arm districts (Table 10). Event mean concentrations for suspended solids, total phosphorus, and total lead are lower in the south arm. It is quite apparent that the retention basins upstream are removing materials from the south branch. Thus much of the pollutant load, in the south arm, especially during small storms, has already passed through basins similar to the one under study. Therefore, it can be expected that the percent removal of total load in this basin will be lower than if all the water entering the basin was directly from the land.

Another factor which affects the actual performance of this basin is the particle size distribution (actually measured by settling time) present in the inlet waters. It was originally anticipated that a large fraction of the suspended solids in the runoff waters would be in the upper ranges above 62 micron. The actual data collected shows that the sizes tends to be smaller and thus require longer detention times to settle from the water column. In general, all of the data collected during this study tends to show a larger portion of the particles are in the smaller ranges. The south inlet location is further impacted due to the presence of the upstream retention basins. The distribution of the particles directly impact the removal efficiencies. As the distribution moves toward the smaller sizes longer detention times will be required to maintain a target efficiency level.

The design of a retention basin and the flow conditions of urban runoff have an important impact on the performance of the basin. As mentioned previously, the Pittsfield-Ann Arbor retention basin was not designed to optimize sedimentation, as the original function of the basin was for

flood control. The outlet structure for the basin is a concrete broadcrested weir which is relatively short in length, and the bottom of the basin slopes upward toward the weir resulting in only a two foot water depth at the outlet. These conditions results in high velocity contours near the outlet, particularly during the high flow periods, and the potential for scouring of material near the outlet structure.

Stormwater flows are highly variable in nature and thus tend to cause very unsteady flow patterns in the retention basin. This deviation from the "ideal basin" will generally result in reduced performance due to short circuitry, disruption of smooth settling profiles and possible disturbances in the sludge zone. In addition, the data collected during this study indicates that the highest levels of suspended solids tend to occur during peak flow rates. Thus, the highest loads are entering the basin during the shortest detention times and least ideal conditions. These general stormwater characteristics and specific basin design conditions were considered in evaluating the performance data.

Comparing the detention time conditions and suspended solids levels (Table 11) shows several trends in the data. The peak suspended solids levels, event mean concentration, and removal percentages were ranked according to the peak flow/minimum detention time and average detention of each storm. Both peak concentration and event mean concentration followed a decreasing pattern as a minimum detention time increases. In addition, the percent removal of suspended solids tends to increase with increasing minimum detention time (i.e. smaller peak flows). These trends do not appear to hold for comparisons with average detention time which is

based on average runoff flows. This data suggest that the peak flow rates are a significant controlling factor in the performance of the basin.

The dependence of the basin performance and event mean concentrations on the peak flow conditions rather than average conditions appears to be the results of the importance of the peak load quantities to the total load, the increased potential for short circuiting during high flow periods, and scouring at the outlet due to the high discharge rate. The event mean concentration for the runoff events when ranked with peak suspended solids concentration show that the event mean concentration is strongly influenced by the peak flow level. This factor tends to hold for varying storm types with different rates of peak to average flow. The combination of high flow and high concentration results in a significant percentage of the total load for the event leaving the basin during that period and consequently raising the overall mean concentration for the event. For storms such as those in June, 1979 and September 11, 1980 which had high peak to average flow ratios (9:1 and 7:1 respectively) the event mean concentration was raised due to the sharp peak rate. Thus, when a comparison of event mean concentration to average detention time was made, the event mean concentrations did not follow the same trend as the other events of more similar peak to average ratios (2-4:1).

The influence of peak flows on the discharge of suspended solids from the basin would be expected during those periods when detention time is quite small such as snow melt and September 11, 1980 events (theo. min. detention time 2.5 hrs.). During these peak flow times, the suspended material has a much shorter period in which to

settle and the most severe short circuiting and turbulence in the basin is probably occurring. High suspended solids levels are entering the basin at this time and some of the solids may be passing through the basin in a much shorter time than the theoretical time of 2-3 hours. This situation can be expected based on the mechanisms involved in the sedimentation process in a dynamically loaded system. However, the increase in concentration also occurs for storms where the peak flows are not as high and the minimum detention time is in the range of 7-8 hours (August 10, October 24, 1980, Table 11). For these events the highest concentrations occurred during the peak flow period even though it is highly unlikely that the load entering the basin had reached the outlet structure. This suggests that scouring is probably occurring at the outlet, resulting in high concentrations during the peak discharge period. Thus, even though the runoff load entering the basin may be settling to the bottom, previously deposited material near the outlet is being flushed from the basin. As a result, the performance of the basin is less than would be expected and the peak flow becomes a controlling factor in the performance of the basin for these storms also.

Based on this evaluation, several possibilities exist for improving the efficiency of retention basins in trapping suspended material. The problem of scouring can be minimized by adjustments in the outlet conditions. Deeper water depths coupled with better control of peak flows or providing a more distributed discharge would help minimize the scour problem. Further the data would indicate that control of the peak flows may be one of the most important factors in the efficiency of a retention basin. Outlet structures which lower the maximum outlet rate could provide better removal during the peak periods. Slowing the

discharge rate will lengthen the detention time in the basin for the peak load periods and thus improve removal efficiency. Another possibility is increasing the size of the basin which will tend to dampen the peak to average flow rates, and will provide additional detention time in which settling can occur. The next section, describing the wetlands, is an example of a larger basin without a restricted outlet. The overall impact of the larger detention times raises the removal levels into the 70-90% range as will be shown.

In summary, the retention basin does remove suspended material from the runoff waters. Site specific conditions, particularly the impact of upstream retention basins, affect the actual percentage removal values for the basin. Higher percent removal values may be achieved in other areas without this influence. Peak flow conditions appear to significantly influence the basin performance and scouring is probably occurring on a regular basis near the outlet. Improvement in the performance of this type of basin could be achieved in future designs by attempting to minimize the scouring problem and improving peak flow control.

Finally, it should be noted tht even though the overall percentage removal levels for this basin may seem low (10-60) a large quantity of pollutants are being retained. For the seven events monitored during this study, over 36,000 pounds of suspended materials were retained in the basin.

Swift Run Wetland

Results

Five rain events and one snow melt event were monitored during the study period. Summaries of the pollutant loadings into and out of the wetland are shown in Table 12. The loadings presented include the total load measured (both baseflow and runoff) during each event. Loadings were calculated using the results from the flow proportional sequential composite samples collected during each event.

Hydrographs of the drain reflected the open channel conditions above the wetland with peak flows being moderately sharp and runoff duration lasting several hours after the rainfall ended. In addition, the very flat slope of the inlet drain and wetland itself tempered peak flows and slowed the water delivery to the wetland. Flow measurements were affected at the inlet by backwater. Therefore, most flow measurements were obtained from the continuous monitor at the outlet structure. Manual depth and velocity measurements at both the inlet and outlet were performed routinely to verify the flow data. Runoff coefficients have been determined for each runoff event and are shown in Table 12. As can be seen, the runoff coefficients vary more widely than for the retention basin, probably due to the influence of considerably more open area which will be more sensitive to soil moisture levels. Runoff levels increased for each April event in 1981 reflecting the very wet conditions occurring during that month of the study.

Table 12. Summary of Pollutant Loads
Swift Run Wetland
Washtenaw County Michigan

Station	Date	Rain Inches	Runoff Volume 10 ⁶ cu.ft.	Runoff Coeff	TSS lbs.	T-P lbs.	TKN lbs.	T-Fe lbs.	T-Pb lbs.
Inlet	08/22/80	1.75	1.2	0.16	5300	13	75	110	1.3
Outlet			1.3		390	7	73	20	< 0.2
% Rem					93	46	3	82	> 85
Inlet	02/81	Snow Melt	3.8		20000	100	420	550	3.2
Outlet			3.8		11000	60	420	410	2.1
% Rem					45	40		25	34
Inlet	04/11/81	1.10	0.56	0.11	2900	4.9	36	38	0.34
Outlet			0.56		500	2.2	26	15	0.08
% Rem					83	55	28	60	76
Inlet	04/13/81	0.79	0.89	0.26	7800	10	74	110	0.68
Outlet			0.89		1700	5	56	50	0.09
% Rem					78	50	24	55	87
Inlet	04/22/81	0.88	1.2	0.30	4100	8	79	97	< 0.4
Outlet			1.2		770	3	59	53	< 0.08
% Rem					81	62	25	45	
Inlet	05/29/81	0.59	0.55	0.21	600	2	45	19	< .08
Outlet			0.55		150	2	33	4	< .04
% Rem					75		27	79	50

The removal efficiency of the wetlands for most of the parameters monitored is very good. Total suspended solids removal efficiencies ranged from 76 to 93 percent for the five rain events. Total iron and lead removal efficiencies are also good with most being greater than 50 percent as high as 87 percent. Again, the iron and lead removal efficiencies are associated with the total suspended solids removals. These metals are mostly present in the insoluble form and therefore would be expected to be influenced by sedimentation processes.

Nutrient removal efficiencies vary between storm events. Some total kjeldahl nitrogen is removed (20-30% efficiency) although most of the kjeldahl nitrogen is present in the soluble form. Usually one would expect the concentrations of these dissolved material to pass through the basin unchanged. However, aquatic plant life present in the wetlands is probably utilizing some of this available nitrogen accounting for the removals seen. Total phosphorus on the other hand is removed fairly consistently with efficiency ranges of 40-60%. One exception to this is seen on the May 29-June 1, 1981 event where no removal is experienced and in fact some material seems to be exported. During this event over 50 percent of the phosphorus is in the soluble form in contrast to the other events where insoluble phosphorus is the major form present. During these events where insoluble phosphorus is the major form however, removal efficiencies ranging from 11-60 percent is experienced for soluble phosphorus. Again, this can probably be attributed to aquatic plant utilization.

The particle size data indicates that there is a small shift in particle size distribution between the inlet and outlet stations. Table 13 summarizes the particle size data

collected for the six events. The outlet station has a larger percentage of smaller sizes reflecting the settling of the larger particles in the wetlands. However, it must be noted that this is a very subtle shift because of the large percentage of smaller sizes (< 4 u) entering the basin. Although data is limited, it appears before a new upstream retention basin (1981) was completed, large particles (< 4 u) made up a larger portion of the particles entering the wetlands. The 1981 event data (after completion of the retention basin) shows that most of the particles entering the wetlands now are in the range of 10 u and below. This would suggest that some settling of the larger particles is now occurring in the upstream retention basin. However, a comparison of total suspended solids event mean concentrations for the monitored events show no clear difference between the 1980 and 1981 events that would indicate the occurrence of extensive sedimentation in the upstream basin.

Table 13. Range of Particle Sizes
Swift Run Wetland

Station	Size	Ave	Min - Max
	Micron	% wt	% wt
Inlet	>60	5	0-10
	4-60	35	10-60
	>4	65	40-80
Outlet	>60	0	0
	4-60	25	10-50
	<4	75	50-100

Fecal coliform results for the August 1980 storm survey shows high levels of coliform entering the wetlands and significantly lower concentrations exiting the wetlands. However, the April and May 1981 events show no significant coliform levels reduction between the inlet and outlet stations. A summary of the levels is shown in Table 14. It should be noted that the coliform levels measured during the 1981 events are significantly lower than those measured during the one monitored 1980 event. Unfortunately not enough data is available to determine if these differences are in fact true conditions. Many variables exist that could account for the difference in these numbers including: time of year, water temperature and effect of the upstream retention basin. Additional sampling would have to be done throughout the summer and fall months to determine if indeed coliform concentrations are or are not affected by the wetlands and at what concentrations.

Examination of the snow melt data shows that runoff during a snow melt period contributes large quantities of pollutants to the Swift Run Drainage Basin. The snow melt event summary data is presented in Table 12. The event occurred in February, 1981 and was the main snow melt of the winter. As demonstrated in the summary tables the wetlands are still capable of removing pollutants but at lower efficiency levels than achieved during the rain events. This can be attributed to several factors, first of which is the tremendous volume of water passing through the wetlands in a fairly short period of time. Although event mean concentrations (Table 14) for the snow melt show that individual parameter concentrations are not greater for the snow melt than for monitored rain events, tremendous loadings into the wetlands (monitored at the inlet station) are being generated due to the large runoff volumes. In

Table 14. Range of Inlet and Outlet Event Mean Concentrations
Swift Run Wetland

Parameter		Min	Max	Ave	Events
TSS mg/l	Inlet	17	139	74	6
	Outlet	4	46	18	6
TKN mg/l	Inlet	1.0	1.7	1.2	6
	Outlet	0.8	1.7	1.0	6
T-P mg/l	Inlet	.05	.42	.18	6
	Outlet	.04	.26	.10	6
T-Fe mg/l	Inlet	0.5	2.3	1.4	6
	Outlet	0.1	1.7	0.7	6
T-Pb mg/l	Inlet	< .006	0.02	0.01	5
	Outlet	< .001	0.009	0.003	6
Fecal					
Coliform CFU/100 ml	Inlet	500	120,000		19*
	Outlet	< 100	4,000		16*

* Total number of grab samples

addition, the wetlands at this time of year is not capable of utilizing any of the nutrient passing through in the runoff. Combining this with the fact that the settling time for the solids is reduced as indicated by the higher event mean concentrations measured at the outlet, the wetlands' removal efficiency mechanisms are definitely hindered during the snow melt period. Total suspended solids, BOD, COD, total and soluble kjeldahl nitrogen, total and soluble phosphorus and total iron event mean concentrations at the outlet are all considerably higher than those concentrations measured during the rain events.

Discussion

As in the case of the Pittsfield-Ann Arbor retention basin, it was anticipated that sedimentation would be a primary mechanism of pollutant removal in the wetland. The basic discussion of factors affecting sedimentation presented earlier for the Pittsfield-Ann Arbor basin also apply to the wetland. One additional potential benefit of the wetland is the removal of soluble materials by the aquatic plants in the wetland.

Table 15 shows the theoretical minimum and average detention time for the various runoff events. Suspended solids concentrations and percent removal levels are also shown. The performance of the wetland was quite good for the runoff events.

The data in Table 15 is ranked by increasing minimum detention time (highest to lowest peak flow). As can be seen, there is a relationship between detention time and peak suspended solids levels and basin efficiency (with the exception of the 8-20-80 event). The much shorter detention

Table 15. Detention Time for Monitored Events
Swift Run Wetland

Date	Min. Detention Time (hrs.)	Ave. Detention Time (hrs.)	% TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS Conc. (mg/l)
Snow Melt 1981	9.3	12	45	70	46
08/20/80	20	33	93	8	5
04/14/81	21	53	78	46	16
04/22/81	24	48	81	22	10
04/11/81	43	67	82	19	15
05/29/81	54	82	76	9	4

times during the snow melt period resulted in higher solids levels at the outlet and a subsequent decrease in removal efficiency. Removal efficiency is higher for the longer detention periods, but appears to level off in the 80% range. There is little difference in the removal for minimum detention times beyond 20-24 hours or for average detention time beyond 48 hours.

As in the case of the Pittsfield-Ann Arbor basin, the peak suspended solids levels tend to follow the peak flows or minimum detention time. Event mean concentrations were influenced by peak levels but not as severely as in the case of the retention basin. The ratio of peak flow to average flow was much smaller and more consistent for the wetland system. Two factors affecting the ratio of peak to average flow are the size of the basin and the upstream drainage system. The wetland is much larger than the retention basin in terms of ratio of volume to typical runoff flow (i.e. longer detention times). This larger size dampens the peak flows and thus lowers the peak to average flow ratios. Dampening the peak flows results in a better settling condition in the basin and reduces the influence of the peak TSS concentrations. In addition, the upstream drainage system is all open channel and drains a relatively flat area. The peak flows are tempered by these physical conditions, thus reducing the stress on the wetland due to peak flow conditions.

The relationships between nutrient inputs (i.e., phosphorus and nitrogen) and the wetland response is somewhat different than the effects of suspended solids, BOD₅ and metals. The response of the wetland is very dependent on the season of the year. During the warmer months when growth is occurring in the wetland, phosphorus

and nitrogen will be utilized by the plants. This process will concentrate the nutrients in the wetland area during the warm months, and thus reduce the concentration of nutrients flowing out from the wetland. With the onset of winter, however, the plants die and the nutrients which have been accumulating begin to be released and flow from the wetland. Thus, during cold weather nutrient levels leaving the wetland will generally be higher than incoming water. During a sampling program for the Drain Commissioner 1977 this effect was noticed in the winter sampling period when nutrient concentrations were higher at the wetland discharge point than the general baseflow levels in the drain. The wetland response to nutrient inputs thus changes the timing of when the nutrients reach the river rather than actually removing or reducing a large portion of the total nutrient load. This change in timing can be a benefit to the river as the nutrient load is delivered during cold months when the impoundments along the river are also releasing their nutrient loads. Thus, the immediate impacts on the river of nutrients released from the wetland will be less than during warm months when the greatest potential for severe water quality problems generally exists.

While much of the nutrient load will eventually reach the river, the wetland area may result in some actual reduction in nutrient load. Studies of wetland systems in Wisconsin have shown that phosphorus removal in 0-30% range may be obtained due to permanent holding of phosphorus in the sediment. Some increased removal of phosphorus can be obtained by harvesting the plant material, but the Wisconsin studies indicated this represented only a small percentage (6%) of the phosphorus load. Some nitrogen reduction may also be obtained due to the reduction of nitrate by natural processes. This reduction is dependent on specific conditions occurring in the sediment and requires an anaerobic environment to occur.

Overall, the wetland provided good control of runoff pollutants for the monitored runoff events. The discharged water quality from the wetland was generally low in suspended solids (5-15 mg/l event mean), phosphorus and lead compared to normal urban runoff. The size of the basin provided this control over the entire size range of monitored rainfall events, all of which were higher than the mean rainfall event for this area. Thus, for typical rainfall events the wetland can be expected to produce an effluent of good water quality when compared with uncontrolled urban runoff or point source discharges. Its interesting to note that during all of the rainfall events the water from the wetland was below the tertiary treatment levels set for the Ann Arbor wastewater treatment plant (10 mg/l TSS, 10 mg/l BOD₅, <1 mg/l T-P).

Traver Creek Retention Basin

Results

Five rain events were monitored during the summer of 1981. Summaries of the pollutant loadings into and out of the basin are shown in Table 16. The loadings presented include the total load measured (both baseflow and runoff) during each event. Loadings were calculated using the results from the flow proportional sequential composite samples collected during each event.

The removal efficiency of the retention basin for most parameters monitored is very low. Total suspended solids removal efficiencies on a mass load basis are less than 35 percent for all of the monitored events. Suspended solids are actually exported from the basin during the May 9-14

Table 10. Summary of Pollutant Loads
Traver Creek Retention Basin
Washtenaw County, Michigan

Station	Date	Rain Inches	Runoff Volume 10 ⁶ cu.ft.	Runoff Coeff	TSS lbs	T-P lbs	TKN lbs	T-Fe lbs	T-Pb lbs
Inlet	04/11/81	1.10	0.73		1,600	3.7	37	24	< 0.06
Outlet			0.54	0.06	1,060	1.4	15	18	< 0.03
% Rem					34	62	59	25	
Inlet	04/13/81	0.79	1.47		5,100	13.1	75	110	< 0.14
Outlet			1.46	0.22	5,450	7.7	76	111	< 0.15
% Rem					0±10%	41	0±10%	0±10%	
Inlet	04/22/81	0.88	1.58		3,620	8.9	99	91	< 0.15
Outlet			1.36	0.18	3,040	6.7	71	91	< 0.11
% Rem					16	25	28	0±10%	
Inlet	05/09/81	0.83	1.13		646	4.1	58	28	< 0.05
Outlet			1.06	0.15	888	2.4	46	23	< 0.06
% Rem					(-37)	41	21	18	
Inlet	06/13/81	1.47	0.33		430	2.0	22	17	< 0.04
Outlet			0.30	0.02	323	0.77	14	8	< 0.06
% Rem					25	62	36	53	

rain event. This export of suspended solids is probably due to the unstable retention basin bank conditions that existed during the study period. The retention basin was just recently constructed and the sod along the banks had not stabilized all of the side walls yet. Some side bank erosion problems were noticed during the monitoring periods.

Metal removals, which are usually associated with suspended solids removal and the sedimentation process are also very low for the five rain events. Some total iron removal is achieved in three of the five events. Removal efficiencies of 26 and 50 percent for total lead are measured for two out of the five events. The remaining three events show no lead removal.

Particle size data (Table 17) indicates that there is not the characteristic downward shift in particle size groups between the inlet and outlet stations as seen in other retention basins. In fact, in some cases, greater percentages of larger particles are leaving the basin than had entered the basin. This indicates that either settling of the larger particles is not taking place in the basin or that some settling is occurring but erosion problems are introducing more sediment into the basin after the inlet station.

Parameters that do show consistent removal efficiencies are nitrates (10-61 percent) and total phosphorus with an efficiency range of 25-62 percent. Over 50 percent of the phosphorus present is in the insoluble form which would indicate that sedimentation is the mechanism for removal. However, soluble phosphorus is also being removed with efficiencies ranging from 58-79 percent. Both soluble and insoluble kjeldahl nitrogen also show removal efficiencies with ranges from 0 to 59 percent.

Fecal coliform data collected during three rain events shows that the coliform levels entering the basin are fairly low and that some die off is experienced in the basin as exhibited by the lower outlet concentrations. The long detention time in this basin (50-60 hrs.) appears to provide sufficient time for significant die away to occur.

Table 17. Range of Particle Sizes
Traver Creek Retention Basin

Station	Size	Ave.	Min-Max
	Micron	% wt	% wt
Inlet	>60	0	0-2
	4-60	57	30-75
	> 4	43	25-70
Outlet	>60	2	0-8
	4-60	38	30-60
	< 4	60	45-70

Discussion

The design of the Traver Creek basin provided good control of outlet flow and long detention times in the basin. Table 18 shows the minimum and average detention time during runoff events and the associated suspended solids concentrations for these events. As shown in the

TABLE 18

DETENTION TIME FOR MONITORED EVENTS
Traver Creek Retention Basin

Date	Min. Detention Time (hrs.)	Ave. Detention Time (hrs.)	%TSS Removal	Peak TSS Conc. (mg/l)	Event Mean TSS (mg/l)
6-13-81	54	130	25	20	18
4-11-81	57	65	34	40	31
5-10-81	60	75	+	16	13
4-22-81	62	69	16	63	36
4-14-81	63	65	x	68	60

+ - export of material
x - 0± 10%

table, long detention times are occurring in the basin and the peak flow (minimum detention) is well controlled for these size storm events. It would be expected, based on sedimentation theory and the other results of this study, that high removal efficiencies of suspended solids should be obtained in the basin. The data shows that this is not the case for suspended solids. Data for the phosphorus, nitrogen, and some metals does show some removal of these materials. This type of performance (i.e. nutrient removal, no solids removal) is contrary to the findings of the other portions of the study.

The probable reasons for the relatively poor performance of the Traver Creek basin appears to be due to site specific conditions rather than design problems or more widespread difficulties with the basic BMP approach. A primary cause of the high outlet levels of suspended solids appears to be due to unstable bank conditions and subsequent erosion near the outlet structure. Due to delays in the construction schedule, the basin itself was not completed until the Fall of 1980. Sod had been placed on the banks to stabilize the soil at that time. It was anticipated that erosion would not be a significant problem in the spring. Unfortunately, this does not appear to be the case especially during the April events.

In addition to the physical evidence that erosion problems existed, the data for other pollutants also tend to support this conclusion. Short circuitry of water through the basin was considered a possible cause of the poor performance for removing suspended solids. It was difficult to conceive that short circuitry would be so significant given the very long theoretical detention times (50-70 hours). The fecal coliform data taken at various times

during the event shows that inlet concentrations of coliform did not appear at the outlet in the same time frame as would occur in short circuitry situations (see Table 19). In addition, phosphorus and nitrogen showed overall reductions in levels, with outlet concentrations being lower than inlet levels. This data would indicate severe short circuiting is not occurring. The nutrient removal occurring in the absence of suspended solids reduction would also indicate that the suspended material being discharged was different in character than the material entering the basin. This would be the case if side bank erosion was occurring during April.

The banks were visually more stable during the May and June events, and the concentration of suspended solids leaving the basin dropped considerably (13-18 mg/l). The inlet level of suspended solids also was lower, however, during these events (9-21 mg/l). In general, the inlet levels of the pollutants being monitored were quite low during the study period. This condition is another site specific condition which appears to have affected the performance evaluation for the basin.

The land in the drainage area above the retention basin is not highly urbanized and the drainage system is a natural open creek type system. In general, all of the concentrations of the various parameters were lower in this drainage area when compared to the more urbanized and densely populated drainage districts such as Allen and Pittsfield-Ann Arbor Drains. It had been anticipated that suspended solids levels would be high in this area during larger storm events due to inputs from the agricultural areas. However, this was clearly not true for this drainage district. The input of relatively low concentrations of

Table 19 Range of Inlet and Outlet Event Mean Concentrations
Traver Creek Retention Basin

Parameter		Min	Max	Ave	Events
TSS (mg/l)	Inlet	9	54	31	5
	Outlet	13	60	32	5
TKN (mg/l)	Inlet	0.81	1.0	0.89	5
	Outlet	0.43	0.84	0.71	5
T-P (mg/l)	Inlet	0.05	0.14	0.09	5
	Outlet	0.04	0.08	0.06	5
T-Fe (mg/l)	Inlet	0.39	1.2	0.77	5
	Outlet	0.34	1.2	0.72	5
T-Pb (mg/l)	Inlet	< 0.0007	0.001	< 0.0009	5
	Outlet	< 0.0009	< 0.003	< 0.002	5
Fecal Coliform CFU/100 ml	Inlet	100	26,000		12*
	Outlet	78	5,500		12*

* Total number of grab samples

materials to the basin in the May and June events (after the banks appeared stable) resulted in little material being available for removal. This is a site specific condition which would not be the case in other urban areas or drainage systems.

The Traver creek basin was built in anticipation of an increased level of development and runoff in the upstream area. The basin design considered the conditions which are expected after the area has been developed. Based on the results for the other BMP's studied, it is anticipated that this basin will be very effective in controlling the urban runoff. Unfortunately, given the conditions which occurred during the study, the monitoring data can not strongly support this opinion.

Huron River

Results

The Huron River and five major drain outlets were sampled twice during this study. A snow melt survey occurred in February 1979 and a summer rain event was monitored in August of 1979. River sampling began on February 22 and continued until February 26 during the major snow melt. On February 23 the temperature rose to forty degrees (°F) and sampling of the five drain outlets was performed. The weather turned colder on the night of February 23 and remained below freezing until February 26, 1979.

The pollutant loads (solids, nutrients and metals) measured in the drains are shown in Tables 20. In reviewing this data, it can be seen that the largest flow and loads

TABLE 20

Pollutant Loads
Snow Melt Survey
Ann Arbor, Michigan

February 23, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	5,432				
pH	(S.U.)	7.85	5,389	235	338	200
Total Dissolved Solids	lbs.		7.94	7.77	7.99	7.89
Total Suspended Solids	lbs.	680,300	467,800	39,000	27,700	21,200
Biological Oxygen Demand	lbs.	70,000	39,000	1,300	3,400	700
Total Kjeldahl Nitrogen	lbs.	8,500	5,700	450	690	200
Soluble Kjeldahl Nitrate	lbs.	1,400	500	32	50	22
Total Phosphorus	lbs.	1,060	400	29	31	15
Soluble Phosphorus	lbs.	700	400	36	37	8
	lbs.	170	63	2	5	1.3
	lbs.	47	10	0.6	1.7	0.1

TABLE 20 (Cont.)

Metal Loads
Snow Melt Survey
Ann Arbor, Michigan
February 23, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft)	5,432	5,389	235	338	200
Iron	lbs.	1,800	970	33	60	20
Soluble Iron	lbs.	13	3	1.2	0.4	0.4
Lead	lbs.	138	46	0.8	4.1	0.9
Soluble Lead	lbs.	2.7	0.7	0.07	0.12	0.02
Zinc	lbs.	193	64	2.6	5.3	0.7
Chromium	lbs.	26.8	19.1	0.4	0.8	0.2
Cadmium	lbs.	4.7	0.5	0.02	0.03	0.002
Copper	lbs.	33.9	12.8	0.3	0.5	0.2
Nickel	lbs.	10.8	3.4	0.2	0.5	0.09

are from Allen Drain followed by the Pittsfield-Ann Arbor Drain. This essentially follows the same pattern as the land use/cover for the drains with Allen Drain representing the heart of the city and Pittsfield-Ann Arbor the largest drain in the City. The flow from these two drains was substantially higher during this period. Observations indicated that this was due to the large amount of snow melted along the roadways which constituted a larger percentage of area in these two drains as compared with the other drains that have substantial amounts of open undeveloped areas in the upper portion of their districts. The melt event monitored here represented the first major and largest snow melt of the season and virtually cleared the main street area of snow. Thus, the high loads of Allen and Pittsfield-Ann Arbor Drains represent a major portion of the snow melt from impervious surfaces in these districts. The other drains were receiving runoff but not nearly as high a total amount in relationship to their size.

When looking at the snowmelt data on a pounds/acre basis, Allen Drain and Pittsfield-Ann Arbor Drain clearly show more runoff and loading per acre than the three other drains. These higher values per acre again reflects the more densely developed areas, greater imperviousness and more commercial/industrial land uses that are typical in these two drainage districts.

When examining pollutant loads entering and leaving Geddes impoundment during this snow melt period the following trends are observed. Removal efficiencies of over fifty percent are seen for total suspended solids, total iron, lead, zinc, cadmium, copper and nickel. These high removal efficiencies can be attributed to sedimentation processes occurring in Geddes Pond. Nutrient removal is not

experienced although it would not be expected in parameters that are found mostly in the soluble state as is the case with kjeldahl nitrogen. Fecal coliform levels entering the river from the five drains are reduced considerably by the time the water passes through Geddes impoundment.

The summer water quality survey was performed during the period of August 17 through August 27. The pollutant loads measured in the drains are shown in Table 21. A general review of these tables shows that the highest loads are originating from the Allen and Pittsfield-Ann Arbor Drains. These higher loadings are not just due to the fact that the basins are larger, but these two districts generally have higher concentration of most pollutants and have substantially more runoff and load on a per acre basis. The higher runoff volumes per acre reflects the more densely developed areas, greater imperviousness, more commercial/industrial usage, etc. A good example of this is shown in the total suspended solids data. Allen and Pittsfield-Ann Arbor Drains discharged 14 pounds per acre and 22 pounds per acre of total suspended solids, respectively. Swift Run, Traver Creek and North Campus Drains discharged 2.3, 2.2 and 0.37 pounds of total suspended solids per acre. Another example of this loading difference between drains (i.e. land uses) is shown in the total lead data. Allen and Pittsfield-Ann Arbor Drains, both characterized by having a large amount of roadways, discharged 0.006 pounds per acre and 0.003 pounds per acre of lead, respectively. Traver Creek, Swift Run, and North Campus Drains discharged 0.0009, 0.0002, and 0.00006 pounds of lead per acre. The dramatic difference in these loading levels show quite clearly the impacts of land use and cover on pollutant loads. The loading differences for total suspended solids and lead can also be observed for other constituents such as phosphorus, nitrogen and iron.

TABLE 21
Pollutant Loads
Ann Arbor, Michigan
August 17-20, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	7,705	10,685	832	1,973	145
pH	(S.U.)	7.8	7.8	7.7	8.0	7.8
Total Dissolved Solids	(lbs.)	134,000	195,000	15,000	57,000	3,000
Total Suspended Solids	(lbs.)	52,600	142,000	7,000	9,880	570
Biological Oxygen Demand	(lbs.)	1,900	1,800	110	430	36
Total Kjeldahl Nitrogen	(lbs.)	430	800	47	120	8
Soluble Kjeldahl Nitrogen	(lbs.)	172	270	15	77	4
Nitrate	(lbs.)	200	156	13	77	2.7
Total Phosphorus	(lbs.)	138	60	6	4	1
Soluble Phosphorus	(lbs.)	<5.1	<11	<0.52	<1.5	<0.10

TABLE 21 (Cont.)

Metal Loads
Ann Arbor, Michigan
August 17-20, 1979

Parameter	Unit	Allen Drain	Pittsfield-Ann Arbor Drain	Swift Run Drain	Traver Creek Drain	North Campus Drain
Flow	(1,000 Cu. Ft.)	7,705	10,685	832	1,973	145
Iron	(lbs.)	920	3,310	180	200	16
Soluble Iron	(lbs.)	<16	28	2.2	3.1	0.28
Lead	(lbs.)	21	19	0.70	<4	0.10
Soluble Lead	(lbs.)	<0.48	<0.66	<0.05	<0.12	<0.01
Zinc	(lbs.)	96	95	7.7	18	1.1
Chromium	(lbs.)	7.1	9.7	1.6	0.87	0.11
Cadmium	(lbs.)	<0.18	<0.27	<0.02	0.06	0.002
Copper	(lbs.)	9.7	6.1	0.48	1.4	0.06
Nickel	(lbs.)	<1.0	2.8	0.23	0.35	<0.02

Composite samples of the Huron River from upstream (Argo Dam) and downstream stations (Geddes Dam) were collected over a ten day period. The data shows very little change in water quality at Geddes during and after the runoff period. The higher event mean concentrations for some parameters found at Geddes Dam when compared to values measured at Argo Dam illustrates the influence that the runoff waters do have on this reach of the river. Increases in total suspended solids, nutrients and total iron can be seen. The particle size data shows a slight shift in distribution reflecting the settling out of some of the larger particles in the basin. Summaries of pollutants entering and leaving the impoundment on a total load basis show removal efficiencies of over fifty percent for total suspended solids, total iron, lead, zinc, cadmium, copper and nickel. Removal of nutrients does not occur.

Discussion

It is evident from inspecting the survey data that large quantities of suspended solids are discharged from the storm drains and are retained within the Geddes Pond area. Both the snowmelt and summer surveys support this observation. The data indicates that 80-90% of the incoming solids loadings are retained in the pond. Heavy metals are also being held within the impoundment. Lead and iron, both measured in reasonably high levels, were held within the impoundment in high percentages (60-90%). During the snow melt period, phosphorus also was retained within the pond area while it appears that this was not the case during the summer period using the net mass balance approach.

Numerical water quality standards have been specifically established for lead (50 ug/l) and cadmium (10

ug/l) while suspended solids and nutrients have no numerical standards for comparison. Comparing the standards with projected pollutant concentrations in the Huron River during the snow melt and rain event shows that the lead standard is exceeded during the snow melt. Suspended solids levels are twice the guideline and phosphorus levels increase substantially over the background levels. The increases in these constituents occur only in the river during runoff periods which tend to be of short duration. Thus the exceedance of the standards and/or guidelines is a temporary situation. These short term levels of solids, nutrients and metals do not appear to result in immediate or acute water quality problems in the river during the runoff period. However suspended solids discharges do result in very turbid water and are an aesthetic nuisance problem following storm events.

The solids, phosphorus, and metals levels decrease following the storm events due to sedimentation in the impoundment. This results in the water quality of the river at the Geddes dam overflow being within the standards and guidelines for the various chemical constituent. Thus, it appears that present stormwater discharges do not result in severe water quality degradation in the river and any immediate impacts downstream which could occur are attenuated by sedimentation in the impoundment. This results in protection for downstream river areas through the trapping of pollutants within the Ann Arbor reach of the river. However, the retention of these pollutants within the impoundment area raises the question of long term impacts due to the accumulation of materials in the park area.

The one exception to this general evaluation is the case of fecal coliform. Grab samples of the drains taken during this study, the 208 study, and other surveys have shown that fecal coliform levels in the range of 10^3 - 10^5 can be expected in the runoff waters. These discharges will result in fecal coliform levels above the standard for total body contact of 200 cfu/100 ml. established by the State of Michigan. The levels will be mixed in the large pond volume and with incoming water. Considering mixing coupled with natural die-off it can be estimated that the standard will be violated at various locations for 1-5 days after the storm depending on the size and duration of the event. Thus while water quality conditions in general are not severely degraded immediately during a storm event, water quality standards for total body contact can be expected to be exceeded at certain times, resulting in loss of potential recreational use of this area. The water quality standard for fecal coliform is not actually violated during the storm events due to the wording of the standard. The 200 cfu/100 ml limit is waived if the source of coliform is a non-point source.

As stated before, short term impacts of storm water discharge on this stretch of the Huron River did not appear to be severe for the monitored events. Long term impacts, however, require consideration due to the sedimentation of materials in the Geddes impoundment. The size of this impoundment in relationship to the river flow (54×10^6 Cu. Ft., median river flow - 300 cfs) results in a body of water with characteristics in between a river and a lake. In order to assess the impact of stormwater runoff under typical conditions, the data collected during this study was used to project drain discharge conditions and river conditions for various size rainfall events and on an annual loading basis.

The method utilized combined data on background water quality conditions in the river from STORET, river flow data from the USGS, and the event and annual non-point source loading data collected during this study. This data was utilized to project water quality conditions during storm events for various size storms and river flow conditions. River flows representing the median flow, mean flow, and dry flow (95% of flow values greater than), 300 cfs, 420 cfs, and 85 cfs respectively, were used in this evaluation. Rain event sizes of 0.3 inches (mean) and 0.9 inches (95% less than) were selected for the evaluation of projected concentrations in the river using the established event mean concentrations. Annual loadings, historical data above and below this reach of river, and the monitoring data presented earlier were used to project the quantity of pollutants being deposited in the sediments.

Evaluation of the projected annual loading data indicates that the long term impacts of the storm drain discharges to the river which are of most concern are the nutrient additions accelerating the eutrophication process and the accumulation of sediment in the pond which concentrates metals and destroys the benthic environment. Early studies on the river have shown that nutrient levels increase in the river as it flows towards Lake Erie. The section of river above the Geddes dam station receives virtually no point source discharges of consequence. Thus, increases in nutrients are attributable to non-point sources.

The data collected during this study indicates phosphorus is settled in the colder periods, while no net change in phosphorus was detected during the August survey. It is difficult to conclude that phosphorus is not settling

in the summer time particularly given the additional data which shows that most of the phosphorus discharged is insoluble. Instead, it would appear that phosphorus is being utilized by the biological community, recycled from accumulated materials and is actually being discharged at higher levels than the incoming levels (Argo Dam) during dry periods. This would indicate that the phosphorus discharged by the drains enters the river, is utilized by biological community and is then discharged over a long period of time.

The phosphorus levels at Argo Dam ranged from 0.01 to 0.04 mg/l during current surveys and were in the range of 0.01 to 0.05 mg/l in previous studies. Phosphorus levels measured at Geddes Dam ranged from 0.01 to 0.10 mg/l during the current work and historical data over the past ten years shows a range 0.03-0.10 mg/l. This data shows a trend of generally increasing phosphorus levels. The increase in phosphorus can contribute to the development of eutrophic conditions which can result in a general degradation of water quality. Currently, moderate algal blooms have been noted in the impoundment but severe conditions have not apparently occurred. However, continued increases in phosphorus levels through continued discharge and increased discharge from new developed areas will undoubtedly have significant negative impacts on water quality conditions.

In addition to nutrients, large amounts of suspended solids are discharged from the storm drains (3,000,000 pounds annually). Heavy metals, particularly lead and iron, are associated with these solids materials and are deposited in the bottom of the pond. The data shows quite clearly that most of the solids discharged by the drains settle in the pond. In addition, data from Argo dam shows that very little settleable material enters the pond from upstream

areas. The upstream ponds buffer Geddes Pond just as Geddes Pond buffers downstream areas. The buildup of silt in Geddes Pond is directly attributable to the storm drains in this reach.

It is quite apparent that the urban storm drains can have a major impact on water quality in the Geddes Pond reach of the Huron River. The 208 program identified this area of the Huron River as a segment being impacted by urban runoff and requiring further attention and ultimately control. The findings of this study support the 208 evaluation and indicate even more clearly the role of urban runoff in the area. Current general water quality conditions in the Geddes Pond reach could be classified as fair with no immediate severe water quality problems, but overall deterioration of water quality does occur as the river flows through the urban area. It can be expected that water quality in the river will deteriorate further if increasing loadings to the river continue. New development will result in increased loads to this stretch of river unless management controls are required. The current loads from urban runoff are generated from approximately 10,000 acres of highly developed land. There exists an additional 9,000 acres which can be developed in coming years and have direct discharge to Geddes Pond. This will undoubtedly result in deterioration of water quality and impairment of the recreational facilities which have been developed along the river.

This summary report has been based on the findings of the two year NURP project. The individual storm event data, detailed landuse information and other information is given a lengthy final report. All water quality data has been entered into the USEPA STORET system as utilized by the NURP headquarters team. The reader is referred to these resources for further information.

